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EVERY FARM AN EXPERIMENT STATION.

BY

ERVIN E. EWELL,
First Assistant, Division of Chemistry.

Reprint from Yearbook of Department of Agriculture for 1897.

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[Reprint from Yearbook of Department of Agriculture for 1897.]

EVERY FARM AN EXPERIMENT STATION.

By Ervin E. Ewell,

First Assistant, Division of Chemistry.

INTRODUCTION.

For many years the complaint has been rife in rural communities that the young people look upon the vocation of their parents as uninteresting and excessively laborious, while yielding small financial return and affording little opportunity for amusement. Many a youth has put forth every effort to leave the farm in order to spend his life in some commercial, industrial, or scientific pursuit, only to discover late in life that he has isolated himself from the very center of nature's activities and has abandoned a world of opportunities for scientific study in order to enter upon a life in many ways narrower and more monotonous than the one he scorned in his earlier years.

This is an age of endeavor on every hand to apply the results of scientific research to daily life; an age when laymen are learning the language of science, and when the tomes of scientific literature are being translated into the language of the multitude. Science has thoroughly established its reign over the industrial and commercial worlds, and now with renewed energy seeks for new territory in the home life of the people. This is evidenced by the fact that technical schools are now offering regular courses of instruction for the preparation of teachers of "domestic science," who are to enter upon the task of teaching, in the common schools and elsewhere, the applications of physics, chemistry, and biology to the conduct of the household. The results of scientific advancement are permeating the whole social structure. Science is to the modern civilization what the heart and circulating blood are to an animal. As each heart beat sends a wave of blood that extends to the minutest capillary vessels, so each new discovery goes out from the little group of investigators as a mighty pulsation that sends an enlivening thrill throughout the entire civilized world—a thrill that is felt the more strongly by the individual the nearer he is in education and training to the authors of the discovery. Pulsations of this sort have been coming to the farmer with ever-increasing vigor for more than half a century; but the lessening of the distance between the mass of the rural population and the busy scientists has not kept pace with the rate of discovery.

APPLICATION OF SCIENCE TO AGRICULTURE.

The national Department of Agriculture, our agricultural colleges, experiment stations, granges, farmers' clubs, reading circles, and

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institutes, aided by writers on agricultural topics in books, periodicals, and the columns especially devoted to these subjects in the press of the country, have done much to foster an appreciation of the breadth and interest of the science of agriculture when studied for its own sake, for financial profit, for pleasure, or for the benefit of mankind. The usefulness of each one of these agencies is becoming greater every day. A very large proportion of a daily increasing store of knowledge, the result of years of research and experimentation, is thus being gradually wrought into the form of popular literature and made available to every farmer and farmer's son studious enough to seek them out and read them. We can scarcely hope that the time will come when every farmer in the land will be a graduate of an agricultural school, but it is quite possible that the vast majority of our rural population may speedily acquire the habit of spending the long winter evenings studying the fundamental principles of the natural sciences, in order that they may profit by the results of experiments made in all parts of the world. The winter is the time for planning the work of the busy summer days to follow. All available literature, old and recent, should be carefully and systematically searched for ideas that can be applied in the work of the following summer. It is scarcely possible to do this without learning something that will make the work of the future easier, pleasanter, and more profitable.

There is a very large proportion of the experimental work necessary to the speedy advancement of agriculture that can only be done by thoroughly trained scientists, working with costly and elaborate apparatus, and by carefully planned systematic methods. Another part can be done as well or even better on the farm. Even experiments of the first class have not fulfilled their usefulness until their results have been applied by the farmer in his practical work. Each quality of soil presents a distinctly different problem. There need never be any fear of lack of work for the trained scientists, for, no matter how diligent and fruitful their labors, one of the most conspicuous results of their work for many years to come must be a better appreciation of the great unknown still to be explored.

The farmer's greatest discouragement in entering upon scientific studies is the fact that the scientist speaks in a language unknown to him. The farmer and the scientist must meet halfway. The one must struggle to acquire as much as practicable of the technical language of science; the other must record his results in scientific language and also in the language of the layman. All persons working for the advancement of scientific agriculture should therefore renew every effort to narrow the gulf between the scientists and the hosts of practical agriculturalists, and to develop among the latter a better appreciation of their opportunities for conducting experiments that will be interesting and profitable for themselves, their neighbors, and their descendants. The farmer should be shown that the technicalities of agricultural science are not so intricate as they at first appear. A few hours in study will cause such words as nitrogen, potash, superphosphate, carbohydrate, etc., to acquire a world of meaning and interest. By devoting a few hours every week to the reading of agricultural literature, it is possible for every farmer to be informed in regard to the current advances in his industry. The expense of the necessary books and periodicals can be greatly lightened by organizing clubs and establishing libraries of agricultural literature. A very considerable part of the time of every scientific worker is taken up with the study of the reports of his fellow-workers. It is not only necessary that the farmer should become a student in order to begin experimental work in the right way, but he must remain a student in order to continue his trials of new methods with success and make his farm truly an experiment station.

THE READING CIRCLE AS A MEANS OF RURAL EDUCATION.

One of the most potent agencies that have been devised for popularizing agricultural science is the home reading circle. "Farmers' reading circles," or "extension departments," have been established in connection with the agricultural colleges of several States, among them Pennsylvania, New York, Michigan, Connecticut, and West Virginia. The first-mentioned circle is the oldest, and has considerably the largest membership. This circle and the Michigan circle alike offer five courses on crop production, horticulture, dairying, and like subjects, and when any student passes a satisfactory examination upon a given number of these subjects he receives a certificate.

The extension department of Storrs College in Connecticut offers one course for men and another for women, and sends a member of the faculty to deliver one or more lectures before each circle of ten or more. Commencement exercises are planned for June, 1898. After the text-book course is completed a library of 100 volumes will be placed at the disposal of the circle.

These schools number hundreds of students each in this extension work, and there is a prospect for a rapid increase of membership till nearly every farmer's home in these States will have such a student. The institution of such courses in other States is to be expected. Further information as to opportunities for farmers to study the sciences underlying their art may be found in a paper by A. C. True, Director of the Office of Experiment Stations, on "Popular education for the farmer in the United States," pp. 279–290, this volume. With such facilities every farmer may easily acquire sufficient scientific knowledge to conduct experiments profitably on his own land.

IMPORTANCE OF SCIENCE TO THE FARMER.

Whatever may be the ultimate uses of the products of the farm, agriculture is primarily engaged with the economical nutrition of plants and animals. Agricultural science deals with the relations of physics, chemistry, and the biological sciences to every phase of every problem that the farmer may meet in his daily work. There is ample material in the results of the investigations that have been made in any one of the many branches of agricultural science to illustrate the value of scientific study to the farmer, and to plan a long series of experiments that can be successfully carried out on any well-regulated farm. In the present paper the writer will consider the importance of certain chemical studies of plant nutrition, and describe a few experiments in this line that can be appropriately undertaken by the farmer.

All food for men and animals is directly or indirectly the product of vegetable life. Therefore, before the nutrition of animals and men can be achieved to the best advantage, a thorough acquaintance with the laws governing the nutrition of plants is necessary. For the successful production of any plant an abundant supply of every kind of food necessary for its growth must be present in a readily available form in the soil or in the air. It is just as impossible to grow plants in a soil containing only available nitrogen and potash, or lime and phosphoric acid, or silica and iron, as it is for a carpenter to build a modern frame house with only window glass and nails, or with only boards and mortar. It is just as useless to expect a plant to thrive in a soil deficient in potash, even though abundantly manured with nitrogen and phosphoric acid, as it is to expect the carpenter to build the house with a million feet of lumber and no nails. It is quite as futile to attempt to feed a plant nitrogen in the form of coarse leather scrap as it would be to furnish the carpenter the iron he is to use for nails in the form of pig iron. In brief, every vegetable structure is made up of certain indispensable chemical elements, which must be accessible in available form throughout the period of its growth. It is one of the most important duties of the agricultural scientist to learn what these indispensable elements are and how most economically to supply them in highly available form to growing plants.

PREPARATION OF THE PLANT'S FOOD IN THE SOIL.

The preparation, or rendering available, of plant food for the growing crop is just as important as is the preparation of food for human beings. Much has been learned during comparatively recent years in regard to the manner in which nitrogenous foods are prepared in the soil for the use of plants. While various organic compounds containing nitrogen and salts of ammonia appear to be assimilated to some extent by agricultural plants, it is nitric acid in the form of nitrates that is preeminently their best food. The nitrogen of ammonia salts and organic matter is rapidly changed to nitrates by the microorganisms of the soil, and thus prepared for the use of the plants by processes which have been clearly described in a paper by H. W. Wiley, chief of the Division of Chemistry, on "Soil ferments important in agriculture," in the Yearbook for 1895, pp. 69–102. The speed with which ammonia salts are changed to nitrates depends upon the presence and activity of the nitrifying organisms in the soil and the maintenance of the conditions which favor their growth. The nitrogen of organic matter must first be brought to the form of ammonia by the organisms of putrefaction before it can be nitrified. The proneness to putrefaction of any organic substance will therefore determine the availability of its nitrogen for the nutrition of vegetable life. The better suited an organic substance is for food for the organisms of putrefaction, the sooner will its nitrogen be changed to a form suitable to serve as food for the higher plants. In the light of these facts it is not difficult to understand why the nitrogen of an old shoe is less available as a plant food than the nitrogen of a piece of meat.

The important conditions governing the activity of the nitrifying organisms are little or no acidity and an abundant supply of air and moisture. The moisture, however, must not be so excessive as to prevent the air for any considerable period from permeating the soil.

Experiments made in the laboratory of the Division of Chemistry of the Department have shown the nitrifying organisms from widely separated regions of the United States to be so extremely sensitive to an excess of acid that this is a sufficient reason in itself for every farmer to try the effect of lime on all soils not known to be of a decidedly calcareous nature.

Experiments recently made in France by Dehérain show that stirring the soil greatly increases the rate of nitrification. This result suggests a series of interesting experiments that can be made on any farm. After the land has been plowed for any crop (preferably winter wheat) and harrowed in the usual manner to even up the surface, select a representative strip across the field and stir the soil of this strip to a depth of 3 to 4 inches with a cultivator or spring-tooth harrow every day or two throughout the entire period intervening between the plowing and the sowing of the seed. If there is any benefit to be derived from this treatment it should be manifest in the better growth of the crop. Its true value can of course only be found by comparing the cost of the extra work with the increased yield obtained. It is logical to suppose that any treatment of the soil which will hasten the formation of nitrates from the less available forms of nitrogen in the soil will insure a prompt and vigorous growth of the young plants.

FARM MANURES.

Every farmer has in the unmerchantable residue of his crops and in barnyard manure a valuable means of maintaining the fertility of his soil. If these materials are carefully and systematically returned to the land, the first purchase of commercial fertilizers can be postponed for a considerable time. On a well-managed farm it ought never to be necessary to purchase quantities of potash and phosphoric acid greatly in excess of the amounts actually sold as constituents of the products of the farm. These substances undergo no loss in the decomposition of carefully preserved manures and crop residues, and are usually not readily washed away by rain waters flowing over or percolating through the soil. With nitrogen it is quite different. This element is very likely to be lost in the decomposition of its organic compounds under the action of bacteria, and in the form of nitrates is very readily washed out of the soil. Of the elements necessary for the growth of plants and most likely to be deficient in the soil (potash, phosphoric acid, and nitrogen), from 60 to 90 per cent of the quantities contained in the food of animals are recovered in the manure. The fertilizer value of ordinary food for farm animals ranges from $1 to more than $20 per ton. In the case of many foods the fertilizing value may nearly or quite equal their commercial value. The manure should be considered just as much a part of the return from the feeding of farm animals as are meat, milk, labor, or salable animals. Indeed, the values of the manures produced by sheep, calves, cows, and horses have been stated at from $24 to $30 per year per 1,000 pounds of live weight, and for pigs at $60 per 1,000 pounds of live weight. These figures are based upon actual experiments reported by the Cornell Agricultural Experiment Station.

No farmer would think of allowing the unnecessary loss of a pound of meat, milk, or wool, or of a day's labor of one of his draft animals, but many of them allow as much as one-half of the value of their barnyard manure to go to waste each year. The importance of care in the preservation of manure has been emphasized in the publications of the Department and of the experiment stations of several of the States. Many experiments have been made in this country and in Europe to determine the nature, causes, and means of preventing the losses which occur during the collection, storage, and use of stable manure and crop residues. The causes of losses may be enumerated as follows:

(1) Imperfect collection of the liquid excreta, which possess even greater value than do the solid excreta.

(2) The decomposing action of microorganisms contained in the intestinal tract of animals and in the air, by which there is likely to be a considerable loss of nitrogen, either in the form of ammonia or in the form of uncombined nitrogen.

(3) The exposure of manure to the leaching action of rains or of rain water as it runs from the eaves of buildings, by which the loss of its valuable constituents is very great.

(4) All stable manures and the refuse of many farm crops (particularly straw) contain organisms which cause the liberation of nitrogen in the gaseous form, when grown in favorable media containing nitrates. There is, therefore, a constant danger that the conditions

of the soil may be favorable for the growth of these denitrifying organisms, and that they will cause a considerable loss of nitrogen by rapidly destroying the nitrates contained in the soil. These organisms decrease in number and activity when the manure is stored for some time. In view of these facts, it is evident that fresh stable manure and nitrates should never be applied to the soil at the same time.

(5) It has been the practice among some farmers to incorporate all the straw possible with manures, in order to facilitate the rotting of the straw and thus increase the availability of the plant food contained in it. Considering the objection to inoculating the soil with the denitrifying organisms contained in straw, the practice of plowing under large quantities of this material in the unrotted state is questionable.

COLLECTION AND APPLICATION OF MANURE.

The results of the most recent experiments indicate that manure should be collected in a pit having impervious walls and bottom; that it should be thoroughly compacted and kept well moistened; that it should be protected from the leaching action of falling rain and from streams of rain water flowing from the roofs of buildings or from higher adjacent ground. A farmer could not plan an experiment more interesting and instructive to himself and his neighbors than one designed to determine the relative fertilizing value of manure when carefully and when carelessly stored. The danger of loss in storing manures argues that it is best to apply them to the land as soon as possible. On the other hand, the presence within them of organisms capable of rapidly destroying nitrates already formed in the soil suggests that manures should be stored in such a manner and for such a time as will lessen or destroy the activity of this class of organisms. The bacteriologist, the chemist, and the practical farmer must join hands in trying to solve this problem, which is one of the most important in agricultural science. The scientists must seek out every organism found in manures, study the conditions which favor or hinder its growth, and determine the properties of the substances which are formed during its growth. The farmer, in the meantime, should make careful tests in the field in order to determine the applicability of a given result to his peculiar conditions. It is a comparatively easy task to manure one portion of a field with fresh manure and another portion with manure which has been stored under definite conditions for a certain time. For this purpose the manure produced by a given set of animals should be collected separately for a convenient period (one week, for example), stored where it can be kept moist, closely packed, and sheltered from the leaching action of rain. The storage period may vary from one month to one or more years. When the time for preparing the soil has arrived the manure should be collected for the same period of time as was the stored manure and from the same set of animals fed in the same way. The fresh and stored manures should each be applied to equal areas of land of the same kind. The crops should be harvested separately and the relative yields determined.

A similar experiment should be made with straw or with other crop residues which are not used for fodder or for the bedding of animals. The experiment can be conveniently made with land on which straw is to be used as a manure for winter wheat. While the animals are in the pasture during the summer most farms will have a shed which can be used for this purpose. Weigh one or two loads of straw and pile it up in this shed as early in the spring as it is no longer needed for sheltering the animals. Keep the pile of straw thoroughly moistened until it is time to prepare the land for sowing wheat. The more thoroughly and continuously moist the straw is kept the more rapidly it will decompose. When the time comes to plow for wheat select two convenient equal areas of similar soil and apply this decomposed straw to one and to the other a quantity of "bright," unweathered straw equal to the quantity of straw placed in the shed for decomposition.

In this experiment it is to be expected that, other things being equal, a somewhat better result would be obtained with the decomposed straw than with the fresh, because the rotting has increased the availability of the plant food contained in the former. This factor can be eliminated and a more positive test of the nitrate-destroying power of the fresh straw obtained by treating a portion of each of these experimental plots with liberal applications of nitrate of soda, superphosphate, and potassic manure. In the latter case, equal yields may be expected on both plots, unless the denitrifying organisms contained in the fresh straw cause a destruction of the soil nitrates.

A SUPPLY OF NITROGEN AT A MINIMUM COST.

We have seen that nitrogen is the element most likely to be lost in the storage of manures, and is the one most easily removed from the soil by percolating water. It also costs nearly three times as much per pound as do phosphoric acid and potash.

Nitrogen occurs as a constituent of a multitude of organic compounds, as ammonia or its salts, as nitrous and nitric acids, which combine with bases to form nitrites and nitrates, and as the uncombined nitrogen of the atmosphere. Combined nitrogen in any one of the first three forms, as offered for sale in high grade fertilizing materials, costs the farmer from 12 to 15 cents per pound. Luckily, we have a means of drawing a supply of this element from the immense store of uncombined nitrogen in the atmosphere. The medium by which we are able to bring this nitrogen into combination for the use of plants and animals is the nitrogen-fixing organisms found in the root nodules of leguminous plants (clover, beans, peas, vetches, lupines, serradella, etc.). These organisms and the advantages of leguminous crops for green manuring and for feeding animals have been frequently described in the publications of the Department and elsewhere. No opportunity should be lost, however, to emphasize the importance of this means of obtaining nitrogenous food for agricultural plants. Not only should leguminous plants be used in all cases for green manuring, but they should be grown as extensively as practicable for food for animals. They require little or no nitrogenous fertilization, produce fodders richer in nitrogenous matter than do the grasses and other nonleguminous plants, and for the same weight of food produce a more valuable manure.

There is one precaution necessary to insure the maximum amount of nitrogen being taken from the air by a given leguminous plant. The soil must contain a sufficient number of the particular variety of bacteria suited to form nodules on the species of leguminous plants to be grown. Pure cultures of the particular variety of organism suited to assist the growth of each species of leguminous plants are manufactured and offered for sale in Germany. These cultures have been tried for two years with varying results in England and on the continent of Europe for the inoculation of soils which are to produce plants of this order. Inoculation experiments have also been made by taking soil from fields on which a given leguminous plant has flourished and distributing it over the field on which the next crop of the same species is to be grown. The directions of Salfeld-Lingen for making inoculations with soil may be recommended for trial on the farms of this country. A translation of these directions, as published in Annales Agronomiques, follows:

RULES TO BE OBSERVED IN THE USE OF SOILS FOR INOCULATION OF OTHER SOILS WITH NITROGEN-FIXING ORGANISMS.[1]

(1) For the different varieties of clover, the soil to be used for the inoculation should be taken from a field on which clover has grown well, and on which the last crop of clover has not been followed by serradella, peas, vetches, or lupines.

(2) The same rule is to be followed for serradella, peas, and other leguminous plants.

(3) As the leguminous tubercles which contain, or have contained, the nitrogen-fixing bacteria are in the layer of arable soil situated at a depth of 2 to 8 centimeters (1 to 3 inches) from the surface, care should be exercised to take precisely this layer of soil for the inoculation. After the soil has been selected and collected it should be well pulverized and mixed to facilitate its spreading over the field to be inoculated.

(4) The soil to be used for the inoculation should be applied as soon as possible after its collection. It may be sown with the hand or with a fertilizer drill.

(5) If the soil can not be distributed immediately it is to be preserved in piles and protected from the cold by covering it with a layer of sod.

(6) It is important that these organisms, which possess no power of movement,

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[1] Deutsche landwirtschaftliche Presse, 1897, No. 11; Ann. Agron., 1897, *23*, 287–288.

be well distributed through the soil by a thorough harrowing, after the inoculating material has been distributed over the field, in such a manner that the bacteria will be brought into the layer of soil situated 2 to 8 centimeters (1 to 3 inches) below the surface.

(7) If kainite has been applied to the field it should be well harrowed in before sowing the soil to be used for inoculation.

(8) As has been stated above, the inoculating material should be mixed with the soil immediately after it has been sown. This is especially necessary when the weather is dry and the sun is very hot.

(9) Burying the inoculating material too deeply must be avoided. Deep working is only permissible after the inoculating material has been distributed through the upper layers of the soil by a thorough harrowing.

(10) When it is not necessary to transport the soil used for inoculation to a very great distance there should be no fear of using too much. At least 5,000 kilos may be used per hectare (4.5 tons per acre).

(11) In general, an inoculation is not necessary when a certain leguminous plant has already been cultivated with success on a given soil and no other leguminous plant has subsequently been grown on the same soil.

In making experimental inoculations it must be remembered that the best results can be expected only when the growing plants are abundantly supplied with available phosphoric acid and potash. In planning an experiment to determine the cause of the poor growth of any leguminous plant, the field, or a portion thereof, should be divided into eight parts. One series of four of these should be inoculated according to the above directions, and the other series of four left uninoculated. On one plot of each of these two series use no additional fertilizers; to another plot of each series apply a liberal dressing of superphosphate; treat the third plot of each series with an abundant application of some potash salt; to the fourth plot in each series add both phosphoric acid and potash. In addition, a narrow strip embracing portions of each of the eight plots can be appropriately treated with lime, unless the soil is known to be already well supplied with this substance.

USE OF "CATCH CROP" TO MAINTAIN A SUPPLY OF NITROGEN IN THE SOIL.

The ease with which nitrates are washed out of the soil by excessive rainfall indicates that the ground should be covered by crops that will use the soil nitrates for their growth during the fall and winter months in climates where there is an abundance of rain during this period of the year. Some crop should, therefore, be started in the late summer or autumn, before or after the removal of corn, potatoes, and similar crops. For this purpose leguminous plants are eminently suited, since they not only feed upon the nitrates formed during the summer, but they also have the power of feeding upon the nitrogen of the air. The time-honored practice of sowing clover with wheat in the spring is especially to be recommended, as the young clover plants develop rapidly after the removal of the wheat crop. By the judicious use of "catch crops" in this manner whenever the soil would otherwise lie barren, the supply of nitrogen already in the soil can not only be preserved, but it can be increased by drawing upon the unlimited store of atmospheric nitrogen. Plants thus produced may be used for feeding or may be plowed under as a green manure when the land is needed for the next crop.

MINOR SOURCES OF PLANT FOOD.

When the manure produced upon the farm is found insufficient, a careful study should be made of all available sources of plant food. Each farmer should consider the cost and suitability for his soil of every sort of fertilizing material obtainable. Farmers living near cities should consider the availability for their use of street sweepings and other forms of city refuse. When the farm wagon is sent to the city with a load of produce it is often a simple matter to take home a load of sweepings or other fertilizing material that would otherwise be used to fill up low ground or to pollute some small inland stream. Many of these materials will need to be composted in order to prepare them for application to the land. Any waste animal or vegetable matter not infected with the germs of some disease of man or animals can be appropriately used for the purpose. The making of composts will be found described in any good book on agriculture, but the chemical changes taking place in compost heaps, as well as the microorganisms which cause these changes, strongly call for further study. It may be stated for the present, however, that nitrogenous fertilizers which are already in condition to go on the field should never be composted, because of the danger of losing a part of their nitrogen. Almost any farmer, by carefully looking about him, can discover more or less plant food going to waste which can be obtained for nothing, or at a very small cost. Methods for composting animal refuse, etc., are fully described by Storer and other writers on agriculture.

COMMERCIAL FERTILIZERS.

When we recall that from 7 to 135 pounds of nitrogen, from 3 to 55 pounds of phosphoric acid, and from 3 to 36 pounds of potash are sold with every ton of produce leaving the farm, it is easily understood that sooner or later some of these important plant foods must be returned to the soil. But among the greatly diversified soils of our country there are some in which all of these ingredients do not become deficient at the same time. Some soils are especially well supplied with phosphoric acid, others with potash, and others with nitrogen, while still others are deficient in only one of these three elements of fertility. For example, Professor Hilgard mentions a California soil containing 1,400 pounds of sodium nitrate per acre in the first foot of soil.

It is therefore the duty of every farmer to determine the needs of each one of his fields and then to study the best means of supplying these deficiencies. It is to be hoped that we will soon be able to develop chemical methods for quickly determining what plant foods are lacking in a given soil. This, however, is impracticable in many cases at present. The results of fertilizer tests made at our experiment stations are of inestimable value, but it has not yet been possible to establish a station or substation on every variety of soil. Indeed, many farms include two or more widely different types of soil or of land so situated as to require different treatment. Taking into consideration the writings on agricultural science and the results obtained by the experiment stations, each farmer should inaugurate a series of experiments to determine the best system of fertilization and crop rotation for him to adopt. It must not be expected that a given practice of farming will be the best indefinitely. Father, son, and grandson can not expect successfully to grow the same crops, on the same soil, in the same rotation, and with the same manuring.

The relative prices of various farm products and of various commercial fertilizers change from year to year, and the successful farmer must change his practice accordingly. He must strive continually to improve his methods so as to realize the greatest margin between the cost of production and the selling price of his products.

As has been well established for several years, the four elements of plant food which he will chiefly need to consider are nitrogen, phosphoric acid, potash, and lime. The first three are usually the more important, but the fourth one can not be neglected except on soils known to contain it in abundance. Lime may be needed as a plant food, to correct excessive acidity, and to aid in the decomposition of the organic matter of the soil and the liberation of other plant foods. In purchasing fertilizers a guaranty of the percentages of the active constituents just named should always be insisted upon. In applying them to the soil a careful record should always be kept of the total quantity of fertilizer and the actual weight of each of the active ingredients actually applied to each acre or other definite area of land. Until the utility of a given method of manuring has been demonstrated beyond question the fertilizer should be omitted from a representative portion of the field, in order that the difference in the yield on fertilized and unfertilized portions can be observed. The only satisfactory way of determining this difference is to harvest separately and actually weigh and note the quality of the product from equal areas selected in fertilized and unfertilized parts of the field. The difference in value of the two yields can then be compared with the cost of the system of fertilization employed. Far too often the farmer is satisfied merely to note the difference in color or height of the crops growing on fertilized and unfertilized portions of the field.

When there is no other means of forming an opinion in regard to the nature of the supply of plant food in the soil of any farm, its fields should be divided into eight representative portions. These portions should be so arranged as to prevent as far as possible the vitiation of the results of the experiment by differences in the character of the soil. One of the portions of each field should be fertilized with nitrogen; a second, with phosphoric acid; a third, with potash; a fourth, with nitrogen and phosphoric acid; a fifth, with nitrogen and potash; a sixth, with phosporic acid and potash; a seventh, with nitrogen, phosphoric acid, and potash, and an eighth should be left unfertilized. In addition, lime should be applied to a strip of land so selected as to cross each of the plots just mentioned. The value of the experiment would be increased by dividing each of the plots into two portions and applying to one part just one-half of the dose of fertilizing material applied to the other part. This would give an indication of the proper quantity of plant food to be applied. Whenever leguminous crops can be made to form a part of a rotation, nitrogenous manures are preferably applied to the other crops of the rotation.

Any farmer desiring to undertake a systematic experiment of this kind should apply to the experiment station of his State for instruction in regard to the details of the work, especially in regard to any modifications of the experiment advisable for his particular locality.

FARM RECORDS.

The value of fertilizer tests and of all experimental work on the farm is largely lost if accurate and complete records are not kept of the conditions and results of each experiment. There is probably no other industry having an equal amount of capital invested in which as little bookkeeping is done as is the case with farming. The farmer should keep an accurate record of the crop growing on each field each year, the quantity and chemical composition of fertilizers used, the yield obtained, the cost of production, and the selling price of the product. Means of weighing are now at hand on a very considerable proportion of farms, and a little time is all that is needed to produce records that will become of inestimable value in a very few years.

Similar records should be kept of the results of feeding animals for the production of milk or meat. The quantity, kind, and value of the food, the length of the period of feeding, the weight, age, and cost of the animals at the beginning, and their weight and value at the end of this period should be noted in the case of animals fed for meat production. For dairy cows, the weight of milk, butter, etc., produced should also be noted.

All records should be kept which are necessary to enable the farmer to know at what cost he produces each bushel of wheat, corn, and oats, and each pound of meat, milk, butter, wool, etc.

OTHER LINES OF STUDY FOR THE FARMER.

Only one of the many branches of agricultural science has been drawn upon for illustrating the importance of scientific study to the farmer. We have considered at some length the value of a knowledge of the laws governing plant nutrition, a knowledge necessary for the successful production of plants suitable for the food and comfort of man and the domestic animals. It is not only necessary to know how to feed plants, but there must be methods for combating the numerous diseases that so often attack them. By studying the laws of animal nutrition the farmer will also be able to lower the cost at which he produces meat, wool, dairy products, eggs, etc., as well as to reduce the cost of producing and maintaining his draft animals.

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